A Structural Decomposition Analysis of Energy Use Change in Tunisia from 1990 to 2008

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Abstract: The goal of this paper is to explain the causes of changes in energy use in Tunisia during the period 1990-2008 by looking for the relative prominence of various sources of change. The method of the Structural Decomposition Analysis (SDA) were used. Results reveal that Tunisia's final demand shifts and production technology adjustments had opposite effects on its energy consumption. Tunisia's energy saving were caused essentially by changes in how to produce (production technology changes) rather than by changes in what to consume (final demand shifts).

JEL Classification: O13, Q43, R15

Key words: Structural Decomposition Analysis; Input-Output Analysis, Energy Consumption, Energy saving , Tunisia.

Introduction:

The pattern of energy use has changed dramatically over the last decades. Many reasons of this phenomenon have been advanced including: OPEC price hikes, development of more energy –efficient technology, structural shifts in final demand.

The purpose of this paper is to explain the causes of changes in energy use in Tunisia during the period 1990-2008 by looking for the relative prominence of various sources of change. The method of the Structural Decomposition Analysis (SDA) will be used.

In general, SDA is a method that let distinguishing major shifts with an economy by means of comparative static changes in key sets of parameters (Rose and Miernyk, 1988). Its origins date back to the work of Leontief (1941) on the structure of the US economy. The basic methodology has been extended in several ways and widely used in energy studies.

Strout (1966) showed how shifts in technology and final demand affected US energy use between 1939 and 1954.

Park (1982) measured the direct, indirect and income induced energy effects of a change in final demand and estimated the effect of technological change on energy consumption.

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Hannon (1983) compared the energy costs of providing goods and services in the US in 1963 and 1980.

Proops (1984) decomposed changes in the energy output ratio into three factors: changes in energy intensities, changes in final demand and changes in the structure of inter-industry flows.

Cao et al (2010) used a SDA method. They revealed that changes in the total embodied energy requirement for the agricultural sector were due to changes in energy use technology.

Behjat and steven (2010) focused in decomposing the US household energy consumption changes into factors that had affected its growth.

Liao and Wang employed the structural decomposition method to study the increasing trend of china's energy consumption. They found that the structural effect corresponding to mediate inputs and the demand effect resulting from investment and export demand were the driving forces behind rapid growth in the energy consumption.

Lin and Polenske (1995) calculated the contribution of technological changes and structural shift based on the data of 18 sectors from 1981 to 1987.

Zhao et al (2010) illustrated that structural shifts played a negative rate on the increase of energy intensity.

Hongung and René (2013) applied a decomposition analysis of changes in energy intensity in China for non residential energy use. They proved that a technological change is the main reason why energy intensity measured as energy use per GDP, fell.

Liao et al (2013) used the SDA method at a regional level in order to analyze the changes of Beijing's energy intensity. They found that during 2002-2010, the energy intensity decreased and the changes were due to the technology changes and the final use variation increased the energy intensity.

2. Model Structure:

In this paper, we develop an SDA model in order to look for sources of final energy consumption changes in the Tunisian economy. The starting point of our analysis is a standard static Input-Output model.

Mathematically, the SDA model is derived from the Input-Output model whose structure can be expressed as:

$$AX + Y = X \qquad (1)$$

$$X = (I - A)^{-1}Y \qquad (2)$$

Where:

A: is the matrix of direct input coefficient.

X: is a vector of Gross-Outptut.

I: is a vector of identity matrix.

$(I\text{-}A)^{-1}$: contains the all direct and indirect requirement for producing one unit of final goods or services.

For an energy Input-Output model, the monetary flows in the energy rows in equation (2) are replaced with the physical flows of energy, in order to construct the energy flows (Miller & Blair (1985); Lin (1996)).

In this paper, we use an SDA model to show if the final energy consumption in the economy changes due to changes in production technologies or variations in final demand.

We generate, for this reason, a system of mutually exclusive and completely exhaustive estimation equations. The model energy consumption E in the economy is the sum of the intermediate and direct consumption:

$$E = E_i + E_f = e[(I - A)^{-1} - I]Y + eY = FY + eY \qquad (3)$$

$$F = e[(I - A)^{-1} - I]$$

E: is a vector of total energy consumption.

E_i: is a vector of intermediate energy consumption.

E_f: is a vector of final energy consumption.

F: is a function of production technology measured in terms of technical coefficient matrix A which includes both energy and non energy inputs.

Y: represents the final demand.

Changes in Tunisia's energy consumption from 1990 to 2008 can be formed as:

$$\Delta E = E_{2008} - E_{1990} \qquad (4)$$

$$= (F_{2008}Y_{2008} - F_{1990}Y_{1990}) + e(Y_{2008} - Y_{1990})$$

Where:

($F_{2008}Y_{2008} - F_{1990}Y_{1990}$): represents changes in intermediate energy use, which depends on production technology change (F) and changes in final demand (Y).

$e(Y_{2008} - Y_{1990})$: measures direct energy consumption which is only a function of final demand shift.

Equation (4) of energy use change can be decomposed into two components: one due to the final demand shift and the other due to production technology change. For this reason, we use an hypothetical economy model; with 1990 base period production technology (F_{1990}) and 2008 current final demand (Y_{2008}).

The energy consumption in this hypothetical economy can be written as:

$$E_{F_{1990}Y_{2008}} = F_{1990}Y_{2008} + eY_{2008} \qquad (5)$$

$E_{F_{1990}Y_{2008}}$: measures the amount of energy that would be consumed in Tunisia's economy if the 1990 production technology were used to deliver the year 2008 final demand.

Using the equation (5) as the reference point, we can express the energy consumption changes from 1990 to 2008 as:

$$\Delta E = E_{2008} + E_{F_{1990}Y_{2008}} - E_{F_{1990}Y_{2008}} - E_{1990} \qquad (6)$$

$$= F_{1990}(Y_{2008} - Y_{1990}) + e(Y_{2008} - Y_{1990}) : \text{Final Demand Shift}$$

$$+ (F_{2008} - F_{1990})Y_{2008} : \text{Production Technology Change}$$

Production technology change can be devised into two components: direct energy requirements and direct non energy requirements use. It can be written as:

$$\Delta E_T = eG_{2008}(A_{2008} - A_{1990})G_{1990}Y_{2008} \qquad (7)$$

$$= eG_{2008}(A_{2008,E} - A_{1990,E})G_{1990}Y_{2008} : \text{Changes in energy inputs}$$

$$+ eG_{2008}(A_{2008,NE} - A_{1990,NE})G_{1990}Y_{2008} : \text{Changes in non-energy inputs}$$

This means that the changes in the intermediate energy demand can be caused not only by changes in direct energy input (A_E) but also by changes in direct non-energy inputs.

We summarize the whole structure of the estimation equations, which we have used in our analysis as below:

Structural Decomposition Analysis of Energy Use Changes Factor

Factor	Equation
Final Demand Shift	$(F_{2008}Y_{2008} - F_{1990}Y_{1990}) + e(Y_{2008} - Y_{1990})$
Production Technology Change	$eG_{2008}(A_{2008} - A_{1990})G_{1990}Y_{2008}$
Changes in Energy Inputs	$eG_{2008}(A_{2008,E} - A_{1990,E})G_{1990}Y_{2008}$
Changes in Non-Energy Inputs	$eG_{2008}(A_{2008,NE} - A_{1990,NE})G_{1990}Y_{2008}$
Actual Energy Use Changes	$E_{2008} - E_{1990}$

3. Results:

3.1 Data Source:

In order to construct a Structural Decomposition Analysis (SDA) model of energy demand changes in Tunisia, we need at first to use two tables of Input-Output. We choose in this study to analyze the period of 1990 – 2008. Data are compiled using the system of national accounts (SNA) conventions. The tables were taken from the National Institute of Statistics in Tunisia (NIS). We group final demand sources into:

(1) Household Consumption;
(2) Gross Fixed Capital Formation;
(3) Changes in Stocks;
(4) Exports;
(5) Imports

We subdivide the production activities of Tunisia's economy into 16 industrial groups and present energy-intensive sectors at a more disaggregated level than that of the rest of the economy, as shown in table (1) below:

Table 1: Production Sectors in the SDA model

Code	Sector
Production Sectors	
1	agricultural and fishing
2	Food
3	Ceramic and Glasses materials
4	Mechanic and Electric
5	Chemicals Products
6	textiles, clothing and leather
7	production of diverse manufacturing industries
8	Mining and Minerals
9	Petroleum Products and Natural Gas
10	Electricity
11	Water
12	Building and Civil Engineering
13	Transport and Telecommunication
14	hotels and restaurants
15	Services
16	Commerce and Market Services

The analysis of change in energy use patterns over time requires that each year Input-Output tables be based on the same set of prices. For this reason, we choose 1990 as the base year (so no price changes were necessary for the 1990 table) and we adjust the 2008 table to 1990 prices using the price indices from the National Institute of Statistics in Tunisia (NIS). We use the indices to convert the output in the 2008 table into 1990 constant prices for all industries within their respective sectors.

3.2 Empirical Results:

With the SDA, we studied the source of the energy use change. Tables (2) and (3) give the main results of our SDA modeling. Table (2) gives the energy use changes in Tunisia from 1990 to 2008 and table (3) shows the percentage change of primary energy consumption in Tunisia's economy from 1990 to 2008.

Table 2: SDA of primary energy use changes in Tunisia from 1990 to 2008 (Ktep)

Source		PT&GAZ	ELEC	TOTAL
Actual Change		536,1292	84,5565	620,6857
Demand Source	MEN	1366,8	441,7	1808,5
	FBCF	587,7	165,5	753,2
	ST	-6,3	-0,6	-6,9
	EXPORTS	767,2	151,8	919
	IMPORTS	-957,1	-176,7	-1133,8
Final Demand Shift		1758,3	581,7	2340
Technology Change		-1309,893	-140,9025	-1450,795
Changes in energy inputs		-595,0205	-0,1078	-595,1283
Changes in non-energy inputs		-714,8722	-140,7947	-855,6669

Table 3: SDA on the growth rate of primary energy consumption in Tunisia's economy from 1990 to 2008 (per cent of 1990 total energy consumption)

Source		PT&GAZ	ELEC	TOTAL
Actual Change		38,451495	27,542834	36,483025
Demand Source	MEN	98,027684	143,87622	106,30106
	FBCF	42,150183	53,908795	44,272027
	ST	-0,45184	-0,19544	-0,405572
	EXPOPRTS	55,024026	49,446254	54,017516
	IMPORTS	-68,64376	-57,557	-66,64316
Final Demand Shift		126,10629	189,47883	137,54188
Technology Change		-93,94625	-45,89658	-85,27568
Changes in energy inputs		-42,67521	-0,035114	-34,9808
Changes in non-energy inputs		-51,27105	-45,86147	-50,29489

Results show that energy consumption in Tunisia during 1990 – 2008 has increased by 620,685 Ktep which is equivalent to 36,48%. This high rate of changes was mainly due electricity 84,5565 Ktep , petroleum and natural gas 536,1292 Ktep equivalent to 38,45 %.

We use the SDA to decompose the energy use changes into two parts: the final demand shift and the production technology change. The final demand shift indicates the energy impact of final demand changes while production technology is held constant. The production technology change quantifies the energy effect of changes in production technology with a given final demand. The empirical results show that the final demand shifts were the main predominant factor that pushed the energy use upward. All else being equal, these shifts would increase the energy consumption by 2340 Ktep equivalent to about 137,54 %.

This upward pressure on energy demand however, was driven down by changes in production technology, which reduced energy requirements per unit of goods and services. Holding all other factors constant, production technology changes would decrease the energy use by 1450,795 Ktep or 85,27 %.

The energy impact of final demand shift can be viewed from many different dimensions. In our study, we will interest only in analyzing the sources of final demand. Results show that the expansion in capital investment, the increase in personal consumption and the rise in exports were the main forces behind the energy use increase associated with final demand shifts.

Holding all other factors constant, these three elements combined would result an increase of 3480,7 Ktep in Tunisia's energy consumption. The household sector is the largest consumer of energy accounting for about 106,30 % of total energy consumption.

Concerning the energy effects of production technology changes, results show that the production technology changes increased efficiency improvement from 1990 to 2008 by 1450,795 Ktep or 85,27% on the whole.

Compared with the energy requirements of using 1990 production technology to satisfy the 2008 final demand, the adoption of 2008 production technology saved about 85,27% of the total energy consumption. All these energy savings came from the improvements in energy efficiency-direct energy input coefficients which reduced primary energy use by 595,12Ktep or about 35% and from the non-energy input by 855,66Ktep or about 50%.

The total of energy savings from 1990 to 2008 that resulted from production technology changes 1309,893 Ktep (93,94%) was from petroleum products and natural gas to the saving was very large.

Conclusion:

In this paper, we applied a Structural Decomposition Analysis of energy use changes in Tunisia's economy during (1990 – 2008). Our goal was to look for main sources of changes during the same period. Results reveal that Tunisia's final demand shifts and production technology adjustments had opposite effects on its energy consumption. Tunisia's energy saving were caused essentially by changes in how to produce (production technology changes) rather than by changes in what to consume (final demand shifts).

The most factor of energy intensity decrease was energy efficiency improvements-the reductions in direct energy input coefficients in most production sectors- which were multiplied across the entire economy, through inter-industry Input-Output linkage.

In terms of sector contributions, the production technology changes in the petroleum products and natural gas were the most important sources of energy savings.

The energy efficiency increases in Tunisia's economy between (1990–2008) can be explained by three macro-economic factors: energy conservation programs, the improvements in macro-economic performance and the increases in energy prices.

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